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Citizen science and smartphones take roadkill monitoring to the next level

Diemer Vercayie[1], Marc Herremans[2]

1 *Diemer Vercayie, Natuurpunt Studie, Coxiestraat 11, 2800 Mechelen, Belgium* 2 *Dr. Marc Herremans, Natuurpunt Studie, Coxiestraat 11, 2800 Mechelen, Belgium*

Corresponding author: *Diemer Vercayie* (Diemer.Vercayie@natuurpunt.be)

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Abstract

Road networks, even in industrialized countries, become denser year after year and traffic volumes continue to increase at a steady pace. It is imperative that we monitor the impact of this trend on wildlife, but monitoring roads for flattened fauna is a time consuming effort and roadkill monitoring projects conducted up till now have been relatively small scale both in terms of time and space. This hampers the progress of road ecology analyses at the population level and at larger landscape extents.

We demonstrate that citizen science projects in combination with smartphones and other new technologies allow analysis at this level and extent, and simultaneously offer more complete data for safer transportation and mitigation of roadkill hotspots. Monitoring roadkill with citizen scientists poses certain challenges regarding data quality and people management, but we show that these challenges can be addressed, which allows researchers to benefit from the many other advantages and possible applications of monitoring roadkill with citizen scientists, including raising public awareness on the matter.

Keywords

Citizen science, roadkill, monitoring, hotspots, road ecology

Introduction

Despite the already high density of roads in industrialized countries, road length and density still increase year after year. Moreover, traffic volume increases as well. E.g. in Europe the length of the motorway network increased with 68% between 1990 and

2010, the number of passenger cars per thousand inhabitants increased with 39% between 1990 and 2010 and the number of kilometers driven by passenger cars increased with 22% between 1995 and 2010 (European Commission 2014). As motorways get more congested, traffic increases on minor roads (van Langevelde and Jaarsma 2009, van Langevelde et al. 2009). The environmental effects are numerous and can be categorized in many ways; e.g. biotic and abiotic effects, direct and indirect, short term and long term. Examples of environmental effects are habitat loss, landscape fragmentation, loss of connectivity, pollution and many wildlife road casualties, also known as roadkill (Forman and Alexander 1998, Spellerberg 1998, Seiler 2001, Coffin 2007). Animals killed are not just the young, weak, or ill individuals; healthy adults are killed equally often by traffic in contrast to natural predation (Bujoczek et al. 2011). Many studies have been undertaken to investigate the number of animals killed on specific road sections, but few authors have assessed the impact of road-killed fauna at larger scale extents or at the population level (van der Ree et al. 2011). In an editorial for a special issue of Ecology and Society, van der Ree and colleagues (2011) stated: 'Counting roadkills by itself is not enough to assess whether roads and vehicles endanger the existence of populations or species. Or counting the number of animals crossing underpasses is not enough to assess if populations on both sides have become more viable. (…) The next step is to evaluate how the density and configuration of entire road networks affect the functional relationships within and among ecosystems at the landscape scale.'

Roadkill monitoring projects conducted up till now are relatively small scale both in terms of time and space, hampering analysis at larger scales. Monitoring roads for faunal mortality is a time consuming effort, especially because many more roadkills are discovered when surveys are done on foot or at very slow speeds compared with surveys done by car at higher speeds (> 20 $km.h^{-1}$) (Slater 2002). Therefore researchers have to weigh search effort (in time and space) and the resulting amount of data gathered against available budgets. Here we present a way to gather large amounts of data on a large scale, with relatively little effort. As Devictor and colleagues (2010) already pointed out, citizen science projects are the way to go 'beyond scarcity' of means and data. On the basis of a project carried out in Flanders (Belgium), we demonstrate that a citizen science project based on so called roving records and transect data in combination with new tools like smartphones can take roadkill monitoring to the next level.

Methods

Citizen science and its application to roadkill monitoring

A citizen scientist is a volunteer who collects and/or processes data as part of a scientific enquiry (Silvertown 2009). Citizen science is a relatively new term for an old practice with an established tradition in astronomy, local history, archaeology, natural history or ecology and especially in ornithology (Greenwood 2007). New tools like internet, smartphones and open source tools as Google Maps, gave this practice a new boost

(Silvertown 2009, Bonney et al. 2009). The potential of citizen science in ecological studies is enormous with applications ranging from the traditional ornithological projects for gathering information on species distributions and phenology to detection of invasive species and even prediction of spread of introduced species (Silvertown 2009, Sullivan et al. 2009, Gallo and Waitt 2011, Ashcroft et al. 2011). With help of citizen scientists we can monitor processes on broad geographic scales and on private grounds which would be difficult to monitor in a traditional way (Dickinson et al. 2010).

Despite its advantages for gathering large amounts of data, only in recent years the number of roadkill monitoring projects based on citizen science and web-based reporting increased rapidly (van der Ree et al. 2015) and parallel with the rise of smartphones a virtual explosion of the number of smartphone apps for roadkill registration was observed (Bissonette 2014). How smartphones can improve the quality of data collection in roadkill monitoring by professionals has already been demonstrated by Olson and collegues (2014). Examples of very successful citizen science roadkill monitoring projects are a project initiated in Flanders (Belgium) in 2008 and a similar project initiated in 2010 in California (UCDAVIS) which was later also implemented in Maine (Maine Audubon). Both projects initially only used so called roving records.

Roving records versus standardized data

A distinction can be made between citizen science projects gathering data in a standardized way (like breeding bird surveys) and projects in which data are gathered incidentally or opportunistically as "roving records". In the latter, search effort is not directed, nor accounted for and only 'presence data' is gathered. Websites like www.ornitho.de, www.artportalen.se or www.observation.org, offer the opportunity to enter incidental observations and consult the data entered by other users. The advantage of this way of gathering nature observations is that it results in huge amounts of data. For example the website waarnemingen.be (local Belgian version of observation.org) gathered more than 15 million observations in Belgium (30.528 km^2) since its start in 2008 (waarnemingen.be 2014). Until now little research has been conducted on the information gathered by this kind of projects, but some very promising studies have been published in recent years (Snäll et al. 2011, Sardà-Palomera et al. 2012). The pitfalls of using roving records are numerous and concern, among others, problems related to search effort (in population trend analyses), detectability and observer expertise. However, many of these problems can be addressed during the analyses if good knowledge of the limitations of the data are available or if the roving records are combined with other data sources (Kéry et al. 2010, Yu et al. 2010, Snäll et al. 2011, Sardà-Palomera et al. 2012). The growing number of publications based on roving records shows that the careful use of this kind of data is now becoming accepted in the scientific world (Silvertown 2009).

The main disadvantage of roving records compared to repeated monitoring of transects is the unknown search effort in the former approach. Therefore roving records cannot be used for impact studies where extrapolations to absolute number of victims

per km per year are needed. A possible bias towards higher reporting rates for less common species cannot be detected either. Road type effects and the effect of a higher search effort (more observers on busier roads) are difficult to disentangle. Therefore in the Belgian citizen science project on roadkills (as well as in the project in Maine) an extra module was added to the website to gather standardized transect data. Monitoring fixed transects, however, is more demanding for volunteers and less people will be willing to participate (Bonney et al. 2009). Both methods have their advantages and disadvantages, but we will show that combining these methods for roadkill monitoring and carrying them out with citizen scientists has great advantages.

Challenges associated with citizen science programs

Below we will elaborate on the advantages of roadkill monitoring with citizen scientists, but in order for citizen science programs to be successful they have to meet a few challenges specific to citizen science programs. The most important challenges involve people management and ensuring data quality (Bisonette 2014, Conrad and Hilchey 2011, Dickinson et al. 2010, Gura 2013). Applied to roadkill monitoring with citizen scientists the major challenges concerning data quality are correct species identification, precise spatial location and double counting. Another challenge is spatial bias, but how important these challenges are depends on the research question. As mentioned earlier these problems can be addressed a priori or a posteriori if good knowledge of the limitations of the data is available.

People management, or more specifically recruiting volunteers and keeping them engaged, is probably the biggest challenge for citizen science projects (Conrad and Hilchey 2011, Gura 2013). But if researchers are aware of these challenges, they can be overcome and turn citizen science projects in data goldmines. Below we will show how these challenges were addressed in the Belgian citizen science roadkill monitoring.

Specifications of the Belgian citizen science roadkill monitoring project

The project ‘Dieren onder de wielen’ (freely translated as ‘Flanders flattened fauna’) was a public-private initiative of the Flemish government and the NGOs Natuurpunt and Vogelbescherming Vlaanderen. It started in 2008 and data is still being gathered. The objectives of this project were (1) to identify roadkill hotspots, (2) to collect data to measure the impact of roads and traffic on fauna and (3) to raise public awareness for the effects of habitat fragmentation by roads.

The project focused on Flanders, the northern part of Belgium, with a surface area of 13.521 km^2. The road network in Flanders is the most dense in Europe with 5,08 km per km^2, except for the microstate Malta (European Road Federation 2011). With 359 inhabitants per km^2, Belgium also has the third highest human population density of Europe, after Malta (1.316) and The Netherlands (493) (EUROSTAT).

The advantage of this high population density is the high potential for citizen science projects, which might result in high data density, suitable for roadkill hotspot analysis.

Natuurpunt (Flanders, Belgium) and Stichting Natuurinformatie (The Netherlands) manage the website www.waarnemingen.be (the local version of www.observation.org) through which opportunistic observations of fauna and flora can be registered in a database. When adding an observation of an animal, the observer is able to choose the option 'roadkill' from different 'behaviours'. The project focused on records of roadkilled vertebrates.

There are three different apps available which allow to upload nature observations to the website mentioned above, one app for each of the three main operating systems of smartphones (ObsMapp for Android, iObs for iPhone and WinObs for Windows Phone). These apps were developed by volunteers in collaboration with Stichting Natuurinformatie. Observations can be recorded in the field (without internet connection) and uploaded to the website with just one tap on an icon when an internet connection is available. The advantages of entering data with smartphones is that it is fast, easy and precise. The observer doesn't need to copy observations from his field notebook to the website. Pictures made with the smartphone can easily be added to the observation and all observations entered on a smartphone are directly linked to the current date and GPS location. Since ObsMapp version 5.0 this app is equipped with a speech input option which makes safe recording of roadkills possible while driving.

Since October 2013 an extra module was added to the website to enter systematic roadkill transect data (accessible through www.dierenonderdewielen.be). Volunteers were asked to choose a route (e.g., their route from home to work), enter it on the website and check this transect at least once every two weeks for roadkills but no more than once a day. Double counts of the same individual roadkill by the same volunteer will be rare for most (small) species when volunteers check their transect maximum once a day, because most carcasses persist for less than one day (Santos et al. 2011). For species weighing less than 200 g, carcass persistence is even less than 2,5 hours (Slater 2002). This transect data will be analyzed with a method similar to the study of Roger et al. (2012). The volunteers were asked to fill out the monitoring form on the website for every survey, whether they found roadkills or not, to avoid a bias in the number of roadkills found per km. Based on the resulting data we have no reason to assume volunteers didn't comply with this request. For safety reasons, volunteers were not obliged to stop for identification of the roadkill. This could have an influence on the correct identification of the species, but volunteers were not obliged to identify the roadkill to species level either. It is possible to add observations like 'mammal species' or 'bird species' and volunteers were asked to identify the roadkill as accurate as possible.

Promotion for the project was made to the vast network of members and volunteers of Natuurpunt (95.000 family memberships) and Vogelbescherming Vlaanderen and through regular coverage in different media (journals, magazines, newsletters, television, radio, …); this was instrumental in generating public awareness for the issue and recruit volunteers to enter observations of roadkills. Efforts were made to keep

volunteers monitoring transects engaged by sending them a monthly newsletter with information on what to expect, feedback on results and applications of the data.

To assure data quality observations of rare species, species which are easily confused with other species and observations with pictures are verified by administrators (volunteers with expert knowledge). Of all roadkill observations that were verified (anno March 2015) only 2,04% got a different species name, but this could be as well in the positive sense (from higher taxon to lower, e.g. 'mammal unknown' to 'rabbit') as the negative sense (from one taxon or species to another or higher taxon). Another 0,85% were labeled 'not assessable'.

Performance of citizen science roadkill monitoring

During the project period (2008/05/15–2014/11/30) 48.517 roadkills of vertebrates on Flemish roads were registered on the website by more than 2000 volunteers. This is a mean density of 3,6 roadkills per square kilometer or 0,7 roadkills per kilometer of road. Therefore, the project resulted in one of the largest and probably the densest dataset on roadkills in the world. This allows for instance to make detailed hotspot analyses, but when analyzing the data researchers should keep the limitations of the data in mind. Based on a subsample of the data we estimate the double counts at about 4% of the total dataset. When analyzing a certain hotspot these double counts can be disentangled by looking at the date and observer for each roadkill. This type of data is not used to estimate the actual number of roadkills per kilometer for a given time period, because these are roving records and therefore there is no account of search effort.

Thirteen months after the start of the systematic monitoring of routes 78 volunteers were monitoring 110 routes for a total of 941 km. Already 2.370 route counts have been registered and 18.995 km surveyed, of which 11.833 km by car, 6.941 km by bike and 221 km on foot. These volunteers found 1.403 roadkills. If we assume a mean speed of 70 km/h for surveys by car, 20 km/h for bikes and 5 km/h for surveys on foot, the effort of these volunteers is comparable to three and a half month of full time work, assuming one can stay focused on roadkills for 7,5 hours per day and 5 days a week.

As expected, it was harder to find volunteers for the systematic monitoring and they recorded only 1.403 roadkills in 13 months, compared to 13.809 'roving' roadkill records of which about 4% were double counts. This comparison clearly shows the advantage of citizen scientists gathering incidental observations of roadkills: almost ten times as much records are gathered with far less effort. Nevertheless systematically gathered roadkill data is necessary for certain analyses as mentioned before and can be carried out with citizen scientists.

The data gathered in the systematic roadkill monitoring is also spatially explicit: roadkill and route positions are registered on the website and can be extracted as digital maps for analysis in GIS software. Therefore all kinds of analysis are possible as for instance relations between number of roadkills and road type, maximum speed or land use.

The roving records data have already been applied to identify roadkill hotspots for single species (e.g., squirrels) or different species together (e.g., amphibians) and mitigation measures were taken for several of them. The project gave information on landscape connectivity issues, distribution of seldom observed or rare species and revealed the most vulnerable species (in terms of most recorded) and seasonal patterns in numbers of roadkill per species. The standardized way of monitoring is currently also being applied to monitor the success of mitigation measures.

Applications and advantages

The applications and advantages of the roadkill monitoring data gathered by citizen scientists are infinite. We list a few important ones below for roving records and transect data separately.

Roving records data

- A ranked list of most vulnerable species can be drawn from both, classical monitoring of transects by researchers and citizen science projects based on roving records, but the latter offer the opportunity to continue the monitoring with relatively few means for many years and monitor the changes in the ranking. This can be a crude way of monitoring species abundance. For instance, in the present study, red fox (*Vulpes vulpes*) was the 3th most frequently reported victim and stone marten (*Martes foina*) was the 9th, while both were not even in the top ten of roadkills during a study in 1995 (Rodts et al. 1998); this increase in road victims parallels their return to many parts of Flanders (Van Den Berge, personal communication 2009).
- Seasonal patterns in numbers of roadkill per species arise from these data.
- Several authors highlight the importance of roving records as a complementary data source for monitoring the distribution of rare species (Snäll et al. 2011, Sardà-Palomera et al. 2012). The large quantity of data gathered in citizen science projects results in a higher chance to detect rare species. This way "the dead can also be used to monitor the living" or more precisely to improve distribution maps (George et al. 2011). Even new species can be discovered by monitoring road kills (Auliya 2002, Covaciu-Marcov et al. 2012).
- By running this kind of monitoring for years, roadkill hotspots and landscape connectivity issues can be detected not just along a few trajectories monitored by researchers, but along most roads in a large project area.
- If the data is made available, governments or other road managers will be able to take evidence based mitigation actions (Greenwood 2007).
- In recent studies (Snäll et al. 2011, Sardà-Palomera et al. 2012) roving records were used to monitor and model species distributions. A next step might be to model and predict roadkill hotspots for certain species on the basis of roadkill monitoring data in combination with Species Distribution Models (SDM).

- A database on roadkills can lead to safer transportation, for instance when it is used as basis for a warning system for wildlife-vehicle collision hotspots on GPS-systems for cars. Such a system could be based on actual roadkill observations or on models. In Sweden such an app for smartphones was launched in 2012 based on the police database of wildlife vehicle collisions (Nationella Viltolycksrådet). A similar app, but based on driver sightings, called AvoiDeer, was developed in Norway (www.avoideer.com).
- Last but not least, involving citizens in roadkill monitoring has the great advantage that it raises awareness for the issue, or as Devictor and colleagues (2010) put it "citizen science promotes the reconnection between people and nature, and between people and science". When the data is made available as a digital map on a website, a direct cooperation and interaction can be established between volunteers gathering the data, researchers analyzing the data and local governments or other road managers responsible for mitigation actions.

Transect data

- Continues monitoring of stretches of road for roadkills by volunteers is a good way to monitor the success of mitigation measures.
- In contrast to roving records, transect data offers the possibility to disentangle the effect of road type or maximum speed on a road and the number of passing observers.
- Potential biases in reporting rates for different species based on roving records can be detected and corrected.
- On the basis of transect data (with known search effort and presence and absence data) an extrapolation can be made to an absolute number of roadkills per km per year and therefore the impact of roads on mortality rates can be assessed. Roger et al. (2012) demonstrated that by combining roving records, SDM and monitoring of fixed transects for roadkills, a (rough) estimate can be made of the absolute impact of roads and traffic on species, taking roadkill studies to the next level.

The advantage of citizen science programs and opportunistic data as a complement to standardized protocols was established earlier by Snäll et al. (2011) for bird monitoring, but from the previous it is clear that it has many advantages for roadkill monitoring too.

Advantages of one portal for all nature observations

Worldwide several portals exist which are restricted to bird records, with or without the option for entering roving records or for monitoring roadkills. We argue that a combination of the possibility to enter observations of all kinds of species, both by checklist or opportunistic observations and the option to label the observation as 'roadkill' has many advantages. Observers add their different kinds of data via the same website

which offers a lot of feedback possibilities and therefore stimuli for the observer, such as for instance an overview of all the observer's personal entries, different statistics and maps and comparisons with other observers. Records of observations of dead or living animals can be combined instantly to produce distribution maps for each species. The combination of records of living and dead animals offers the opportunity to analyze in which areas the species is present but doesn't get killed on roads and areas where it is present and is frequently run over. Therefore, a website and database like www.observation.org, which combines the possibility of entering roving records data of living or dead species for all taxa as well as checklists or transect data, offers the ideal tool for roadkill monitoring. The tools (website, app) of this roadkill monitoring project are available and can be deployed anywhere in the world.

Conclusion

Van der Ree et al. (2011) argued that analysis on larger landscape extents and population level could bring road ecology to the next level. Large datasets spanning large areas based on roving records might be the gateway to this next level. Based on the results of the ongoing roadkill monitoring project in Belgium we conclude that gathering roving records of roadkills and systematic monitoring of roadkills with citizen scientists, facilitated by tools like smartphones indeed deliver big data and take roadkill monitoring to the next level.

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